Combined Heat and Power for Wastewater Applications

Illinois State Energy Office
Wastewater Efficiency Workshop

Graeme Miller
Assistant Director
US DOE Midwest CHP Technical Assistance Partnership
Carbondale, Illinois
October 26, 2018

CHP Technical Assistance Partnerships
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Agenda

- DOE CHP Technical Assistance Partnerships
- CHP Concepts Benefits and Technologies
- CHP and Wastewater Facilities
- Available Utility Incentives
- Next Steps in Evaluating CHP

DOE CHP Technical Assistance Partnerships (CHP TAPs)

- **End User Engagement**
  Partner with strategic End Users to advance technical solutions using CHP as a cost effective and resilient way to ensure American competitiveness, utilize local fuels and enhance energy security. CHP TAPs offer fact-based, non-biased engineering support to manufacturing, commercial, institutional and federal facilities and campuses.
- **Stakeholder Engagement**
  Engage with strategic Stakeholders, including regulators, utilities, and policy makers, to identify and reduce the barriers to using CHP to advance regional efficiency, promote energy independence and enhance the nation's resilient grid. CHP TAPs provide fact-based, non-biased education to advance sound CHP programs and policies.
- **Technical Services**
  As leading experts in CHP (as well as microgrids, heat to power, and district energy) the CHP TAPs work with sites to screen for CHP opportunities as well as provide advanced services to maximize the economic impact and reduce the risk of CHP from initial CHP screening to installation.

www.energy.gov/chp

CHP Technical Assistance Partnerships
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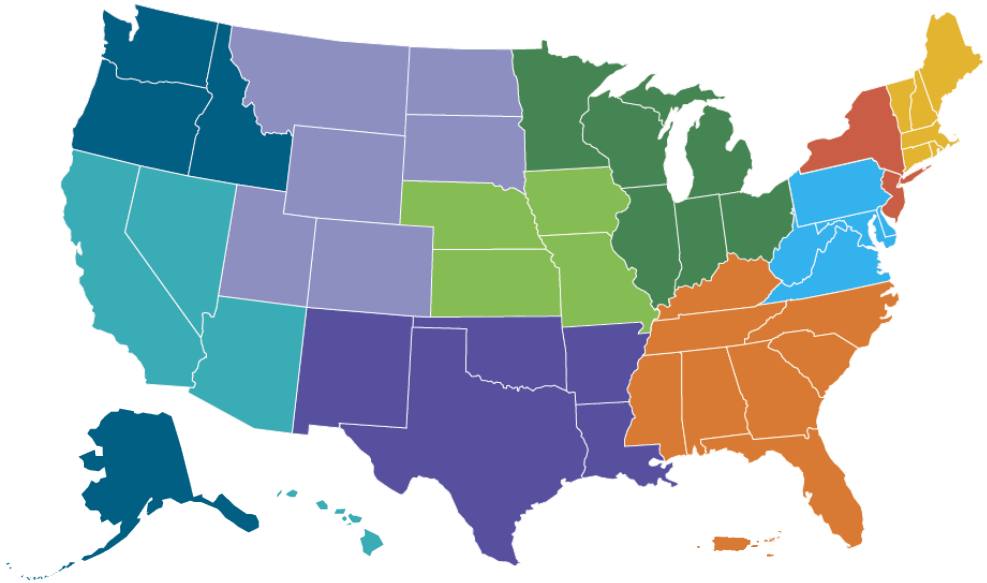
DOE CHP Technical Assistance Partnerships (CHP TAPs)



Northwest WA, OR, ID, AK
www.northwestCHPTAP.org
David Van Holde, P.E.
Washington State University
360-956-2071
VanHoldeD@energy.wsu.edu

Upper-West UT, CO, WY, MT, ND, SD
www.upperwestCHPTAP.org
Gavin Dillingham, Ph.D.
HARC
281-216-7147
gdillingham@harcresearch.org

Midwest MN, WI, MI, IL, IN, OH
www.midwestCHPTAP.org
Cliff Haefke
University of Illinois at Chicago
312-355-3476
chaefk1@uic.edu

New England VT, NH, ME, MA, RI, CT
www.newenglandCHPTAP.org
David Dvorak, Ph.D., P.E.
University of Maine
dvorak@maine.edu
207-581-2338

New York-New Jersey NY, NJ
www.newyorknewjerseyCHPTAP.org
Tom Bourgeois
Pace University
914-422-4013
tbourgeois@law.pace.edu

Mid-Atlantic PA, WV, VA, DE, MD, DC
www.midatlanticCHPTAP.org
Jim Freihaut, Ph.D.
The Pennsylvania State University
814-863-0083
jdf11@psu.edu

Southeast KY, TN, NC, SC, GA, FL, AL, MS
www.southeastCHPTAP.org
Isaac Panzarella, P.E.
North Carolina State University
919-515-0354
ipanzarella@ncsu.edu

Western CA, NV, AZ, HI
www.westernCHPTAP.org
Gene Kogan
Center for Sustainable Energy
858-633-8561
gene.kogan@energycenter.org

Southcentral TX, NM, OK, AR, LA
www.southcentralCHPTAP.org
Gavin Dillingham, Ph.D.
HARC
281-216-7147
gdillingham@harcresearch.org

Central NE, IA, KS, MO
www.centralCHPTAP.org
Cliff Haefke
University of Illinois at Chicago
312-355-3476
chaefk1@uic.edu

DOE CHP Deployment Program Contacts

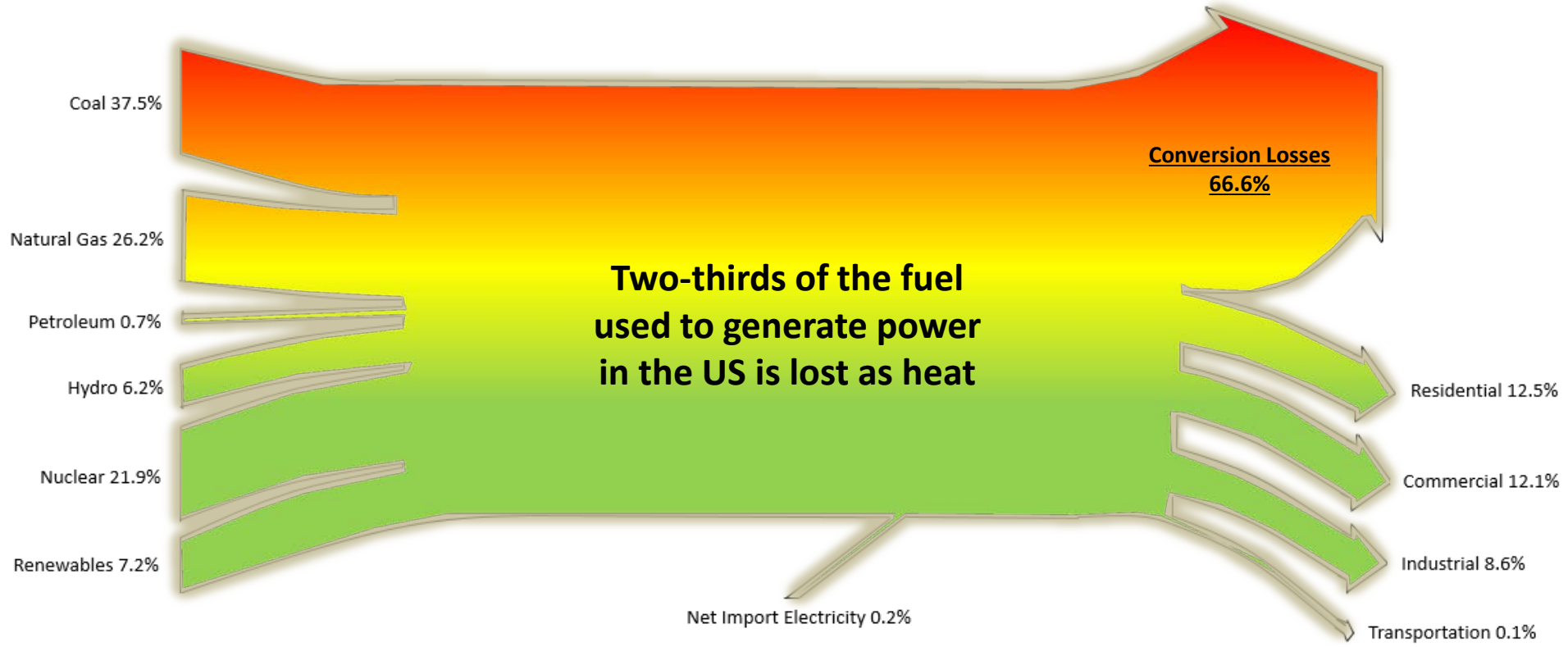
www.energy.gov/CHPTAP

Tarla T. Toomer, Ph.D.
CHP Deployment Manager
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy
Tarla.Toomer@ee.doe.gov

Patti Garland
DOE CHP TAP Coordinator [contractor]
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy
Patricia.Garland@ee.doe.gov

Ted Bronson
DOE CHP TAP Coordinator [contractor]
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy
tbronson@peaonline.com

Energy Utilization in the Utility Sector



Source: https://flowcharts.llnl.gov/content/assets/images/charts/Energy/Energy_2015_United-States.png

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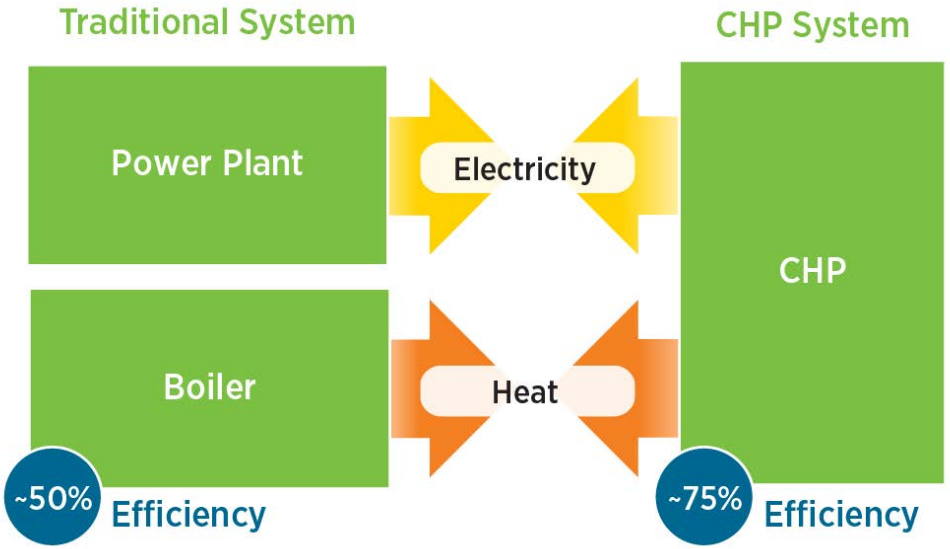
CHP: A Key Part of Our Energy Future

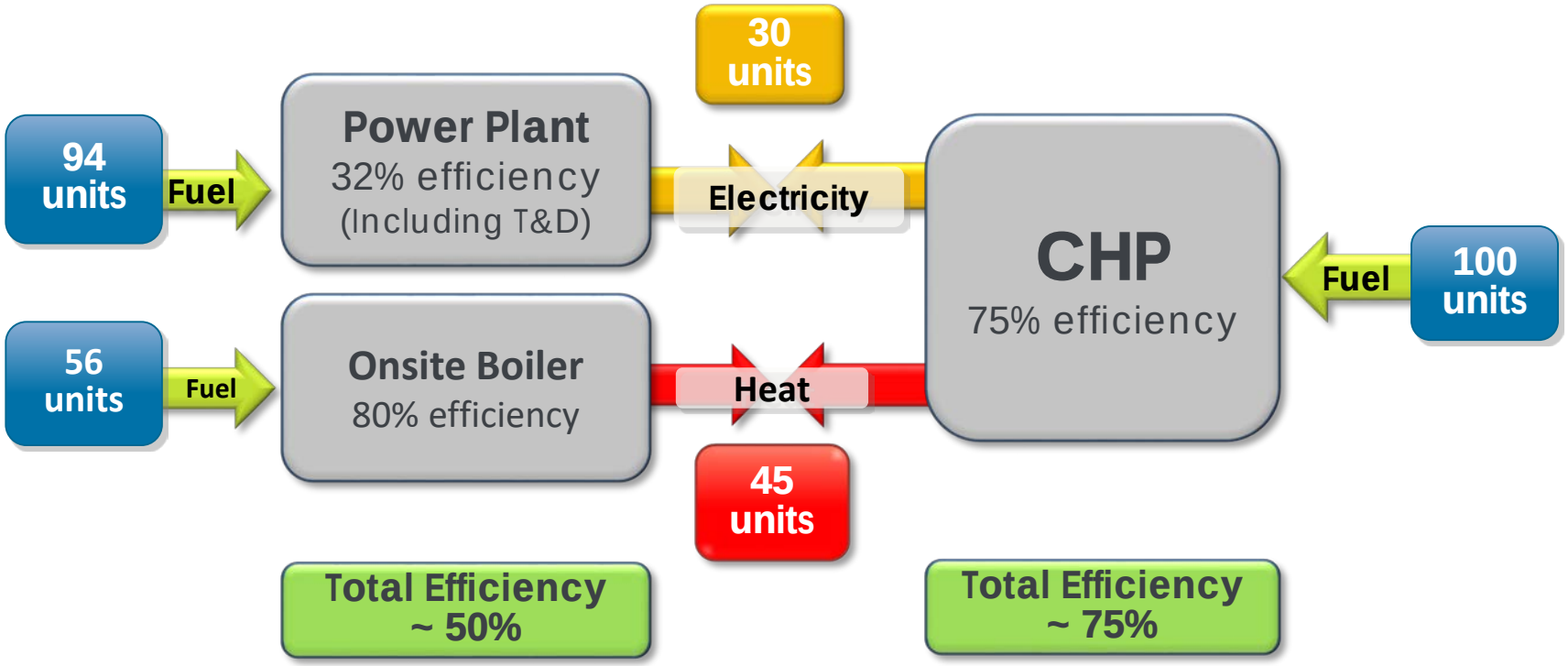
- Form of Distributed Generation (DG)
- An integrated system
- Located at or near a building / facility
- Provides at least a portion of the electrical load and
- Uses thermal energy for:
  - Space Heating / Cooling
  - Process Heating / Cooling
  - Dehumidification



CHP provides efficient, clean, reliable, affordable energy – today and for the future.

Source: www.energy.gov/chp

CHP Recaptures Heat of Generation, Increasing Energy Efficiency, and Reducing GHGs



30 to 55% less greenhouse gas emissions

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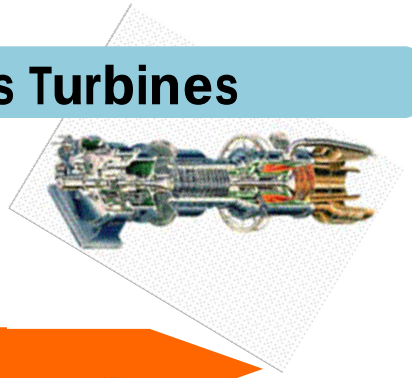
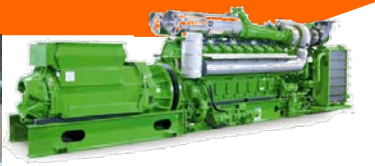
Common CHP Technologies

Microturbines

Gas Turbines



Reciprocating Engines



Fuel Cells

Steam Turbines

50 kW | 100 kW | 1 MW | 10 MW | 20 MW

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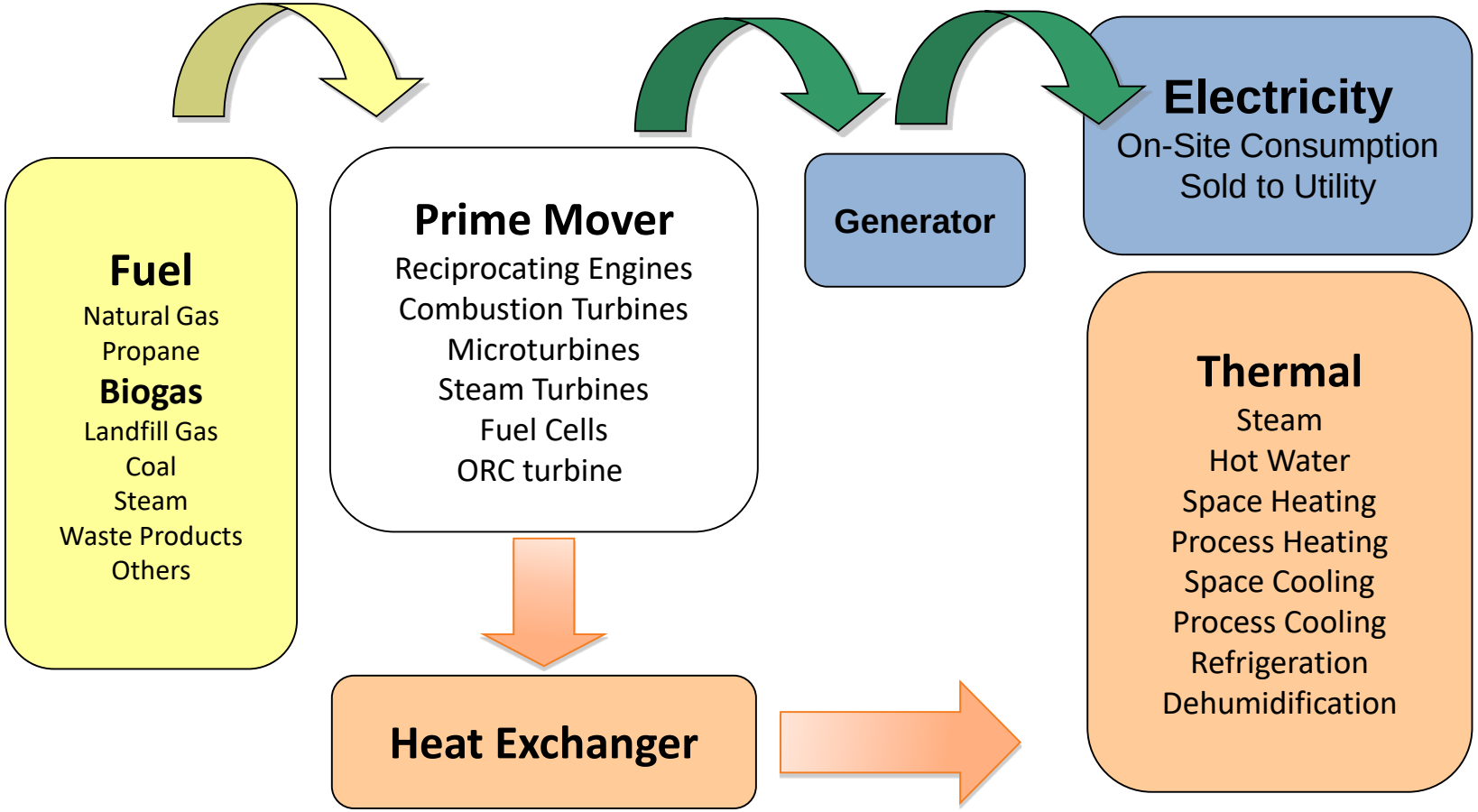
CHP System Schematic



Critical Infrastructure and Resiliency Benefits of CHP

"Critical infrastructure" refers to those assets, systems, and networks that, if incapacitated, would have a substantial negative impact on national security, national economic security, or national public health and safety."

Patriot Act of 2001 Section 1016 (e)

Applications:

- Hospitals and healthcare centers
- Water / wastewater treatment plants
- Police, fire, and public safety
- Centers of refuge (often schools or universities)
- Military/National Security
- Food distribution facilities
- Telecom and data centers

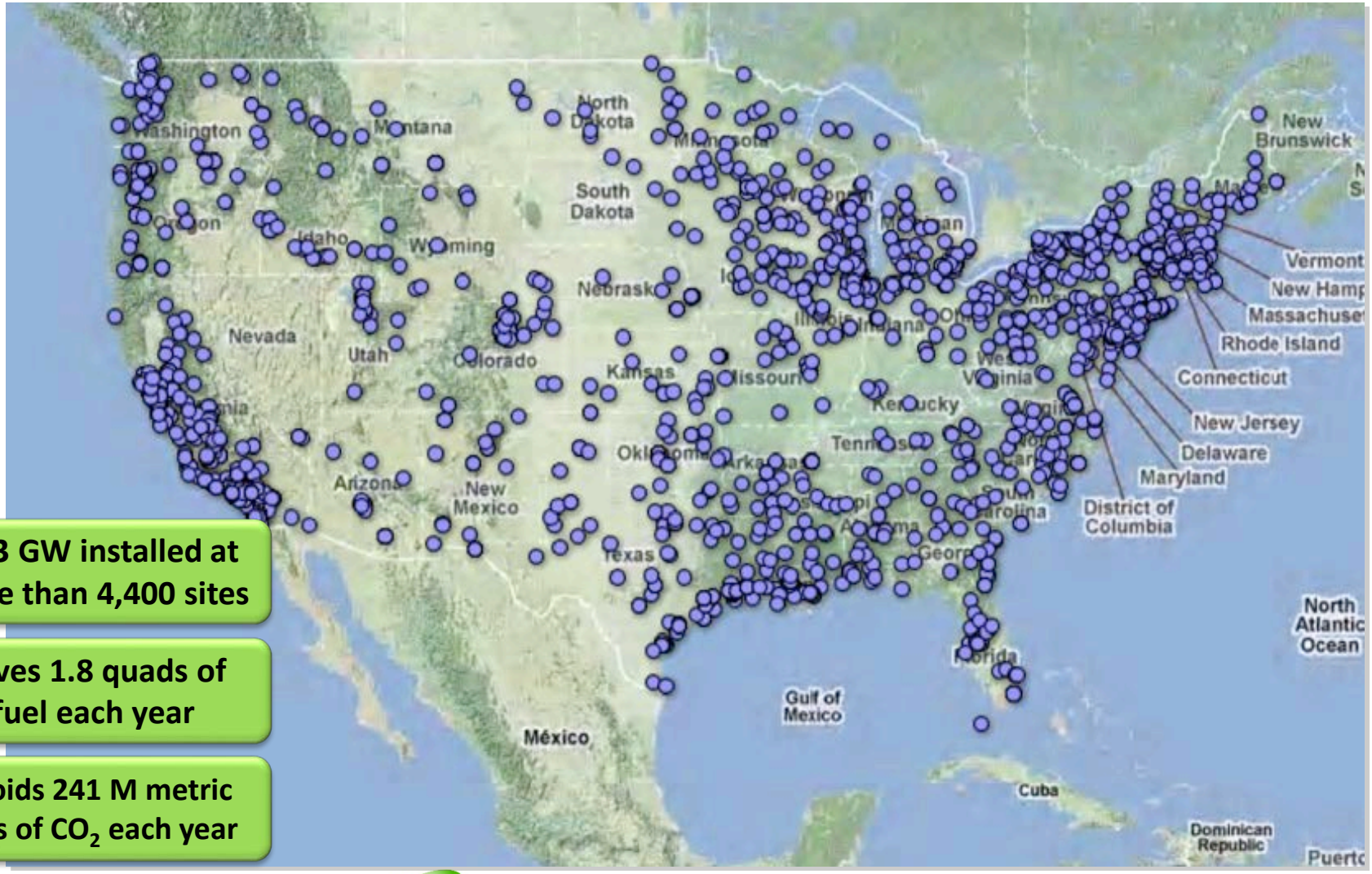
CHP (if properly configured):

- Offers the opportunity to improve Critical Infrastructure (CI) resiliency
- Can continue to operate, providing uninterrupted supply of electricity and heating/cooling to the host facility

What Are the Benefits of CHP?

- CHP is **more efficient** than separate generation of electricity and heating/cooling
- Higher efficiency translates to **lower operating costs** (but requires capital investment)
- Higher efficiency **reduces emissions** of pollutants
- CHP can also increase **energy reliability** and enhance power quality
- On-site electric generation can **reduce grid congestion** and avoid distribution costs.

CHP Is Used Nationwide In Several Types of Buildings/Facilities



81.3 GW installed at more than 4,400 sites

Saves 1.8 quads of fuel each year

Avoids 241 M metric tons of CO_2 each year

Source: DOE CHP Installation Database (U.S. installations as of Dec 31, 2017)

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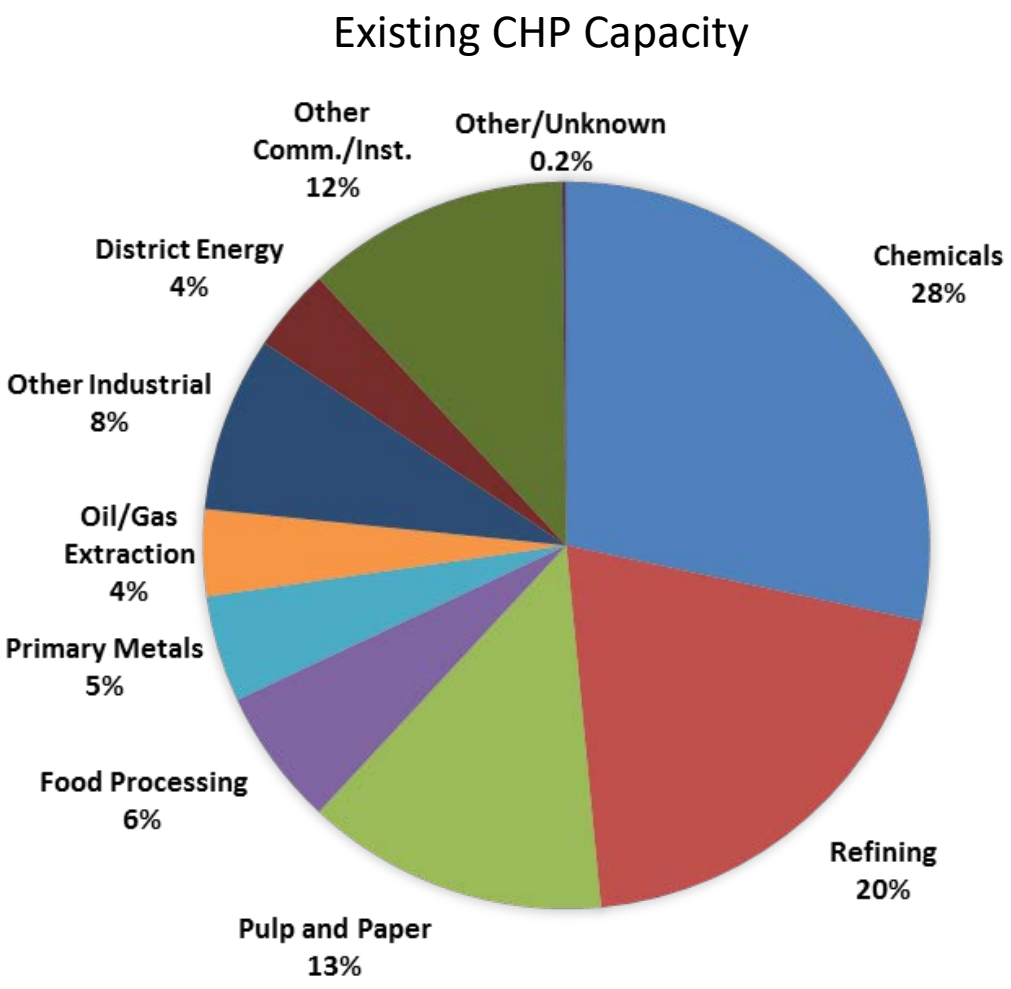
Slide prepared on 7-3-18

CHP Today in the United States



- **81.3 GW** of installed CHP at more than 4,400 industrial and commercial facilities
- 8% of U.S. Electric Generating Capacity; 14% of Manufacturing
- Avoids more than **1.8 quadrillion Btus** of fuel consumption annually
- Avoids **241 million metric tons of CO_2** compared to separate production

Source: DOE CHP Installation Database (U.S. installations as of December 31, 2017)

CHP Technical Assistance Partnerships
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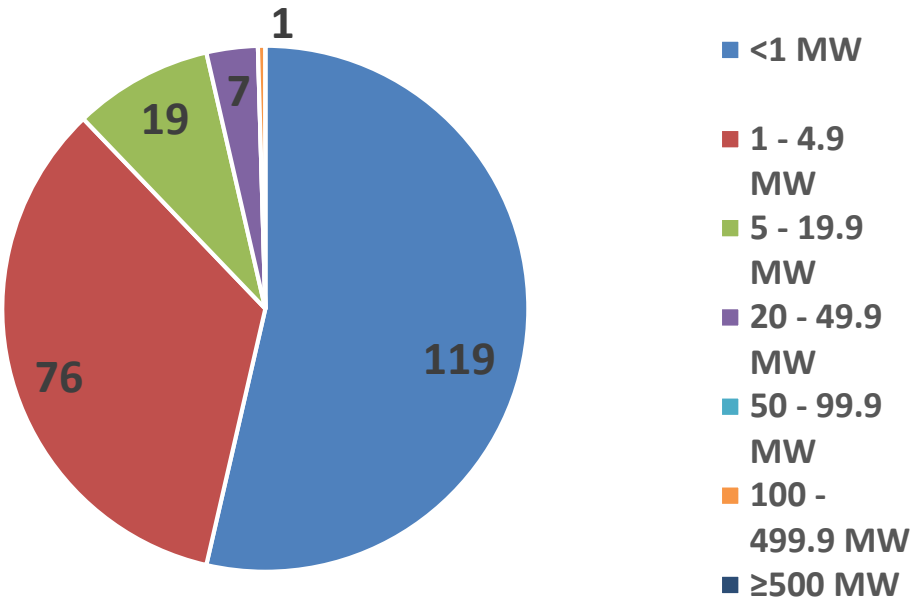
Slide prepared on 7-3-18

CHP in Wastewater Facilities

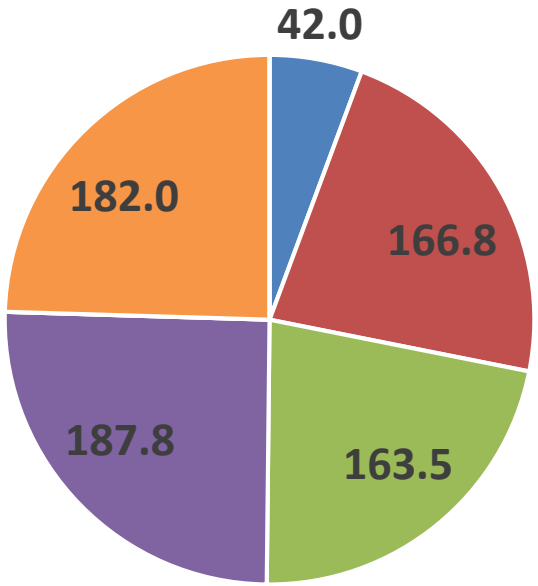
CHP Today in WWTPs

(By CHP System Size)

Number of CHP Systems



Installed CHP Generating Capacity, MW

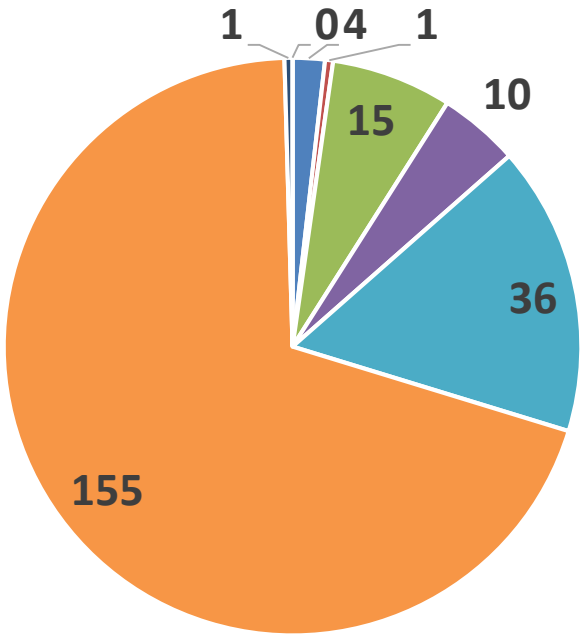


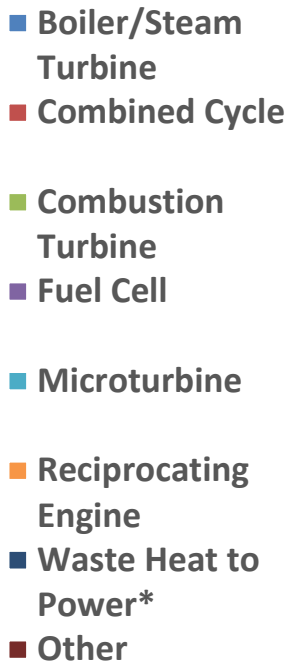
Source: U.S. DOE CHP Installation Database (U.S. installations as of December 31, 2017)

CHP Today in WWTPs

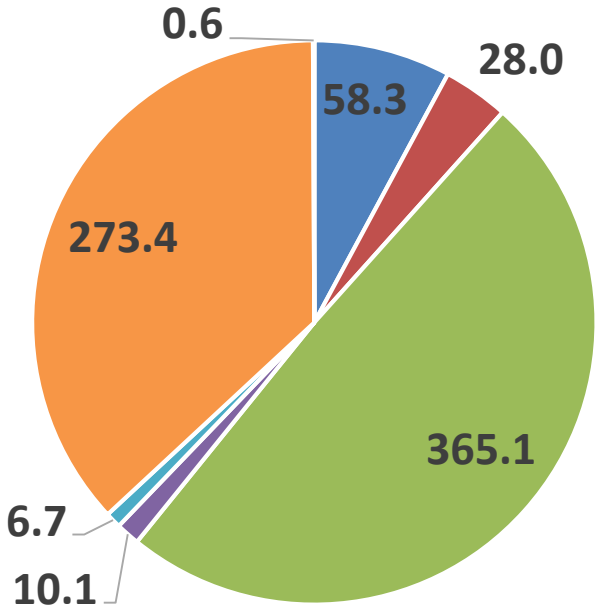
(By Prime Mover Type)

Number of CHP Systems





Installed CHP Generating Capacity, MW

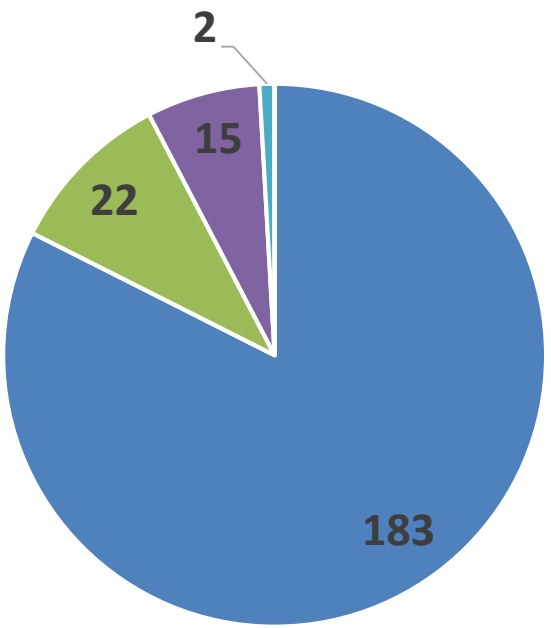


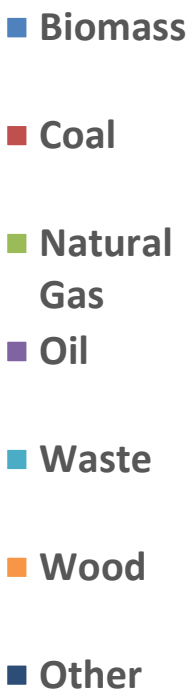
Source: U.S. DOE CHP Installation Database (U.S. installations as of December 31, 2017)

CHP Today in WWTPs

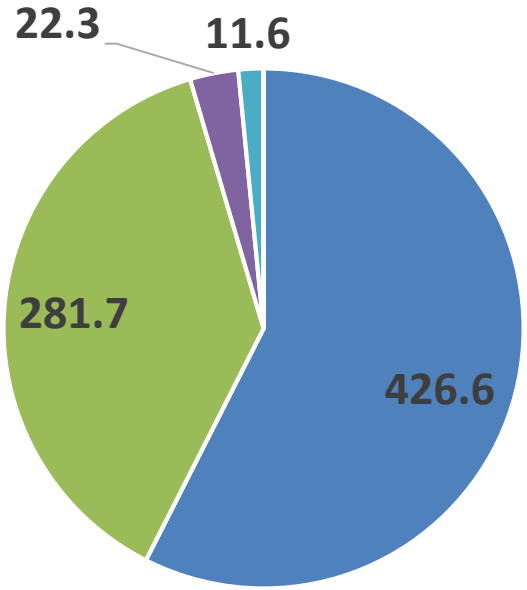
(By Fuel Type)

Number of CHP Systems



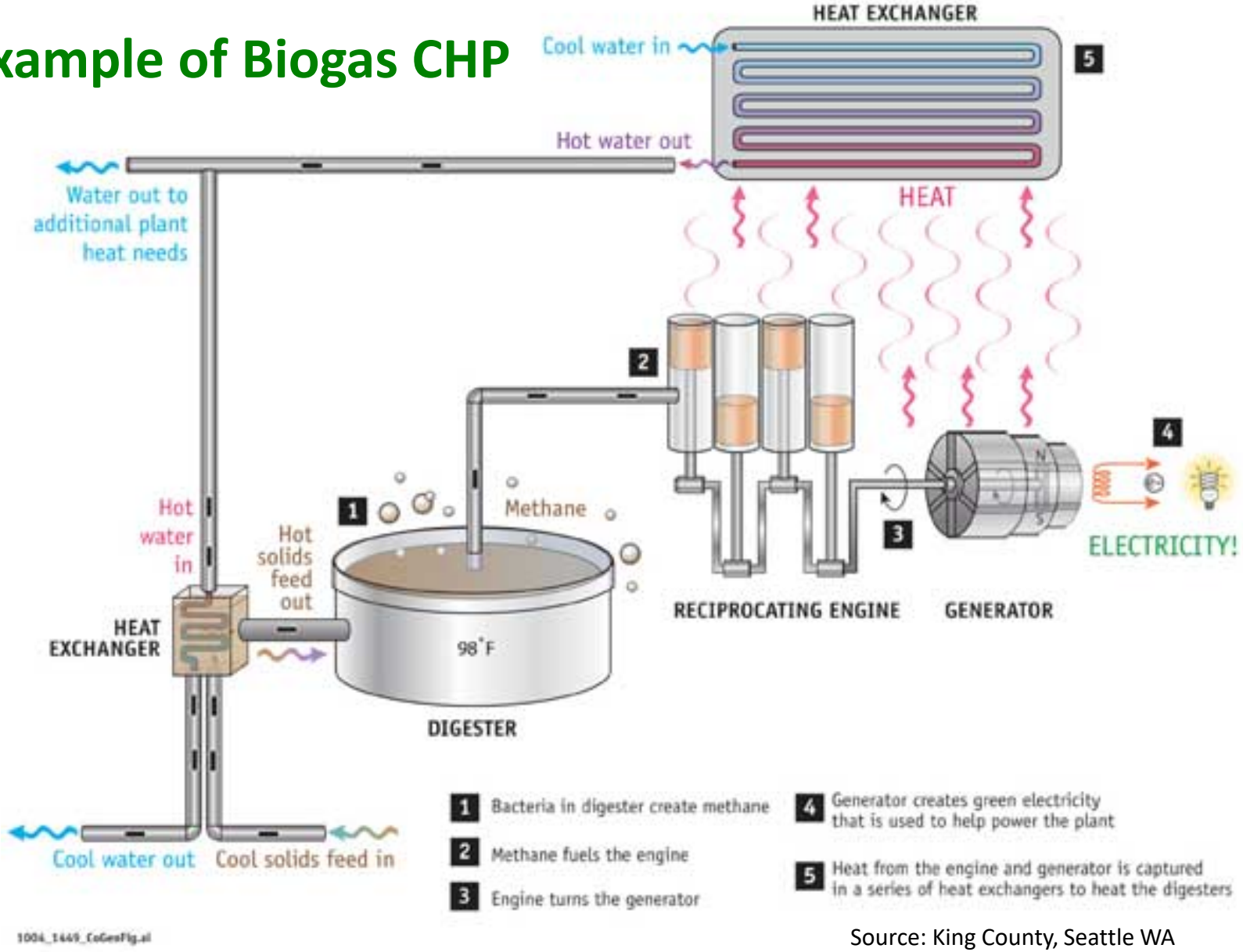


Installed CHP Generating Capacity, MW



Source: U.S. DOE CHP Installation Database (U.S. installations as of December 31, 2017)

Example of Biogas CHP



Source: King County, Seattle WA

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Co-digestion

- Co-digesting different organic wastes can increase biogas production, but care must be taken to understand the characteristics of the combined feedstock.
  - Can affect the quality of the effluents
  - Can impact permitting requirements
  - Is the feedstock you expected the feedstock you actually received
  - Not understanding the characteristics and/or volume added can severely damage the digester

Designing for Reliability

Two Generator Types

- Induction
  - Requires external power source to operate
  - When grid goes down, generator goes down
  - Less Complicated and Costly to Interconnect
- Synchronous
  - Self Excited (Does not need grid to operate)
  - Generator can operate thru Grid outages
  - More Complicated and Costly to Interconnect

Uninterrupted Operation Requirements

- Black start capability
  - Allows the system to start up independently from the grid
- Generators capable of grid-independent operation
  - The system must be able to operate without grid power signal
- Ample Carrying Capacity
  - System size must match critical loads
- Parallel utility interconnection and switch gear controls
  - The system must be able to disconnect from the grid, support critical loads, and reconnect after an event

Lessons Learned: Biogas CHP Projects

Drivers and Benefits

- Energy cost savings
- Federal, state and local utility incentives
- Energy/sustainability plans and emissions reductions
- Green publicity/positive public relations
- Enhanced reliability
- Facility Upgrades
- Increased biogas production
- Enhanced biosolid management
- Utility load shedding

Fun Facts:

A typical WWTP processes 100 gal/day of wastewater for each person they serve

Each million gallons per day (MGD) of wastewater flow can produce enough biogas in an anaerobic digester to produce 30 kW of electric capacity

Lessons Learned: Biogas CHP Projects

- **Technical Challenges**
  - Biogas cleanup & cost considerations
  - Space constraints
  - Staff education/training with CHP operation and maintenance
  - Biogas production fluctuations

- **Other Challenges**
  - Utility issues
  - Permitting issues
  - Biogas supply/Food waste introduction
  - Project Financing

Biogas Conditioning

Is it really required?

Hydrogen Sulfide (H_2S) and Siloxane concentrations are found in the biogas produced from all WWTP anaerobic digesters.

H_2S oxidizes into sulfur dioxide in the combustion process, forming sulfuric acid when dissolved into water droplets. This can damage a prime mover exhaust system, heat exchangers, and stack liners.

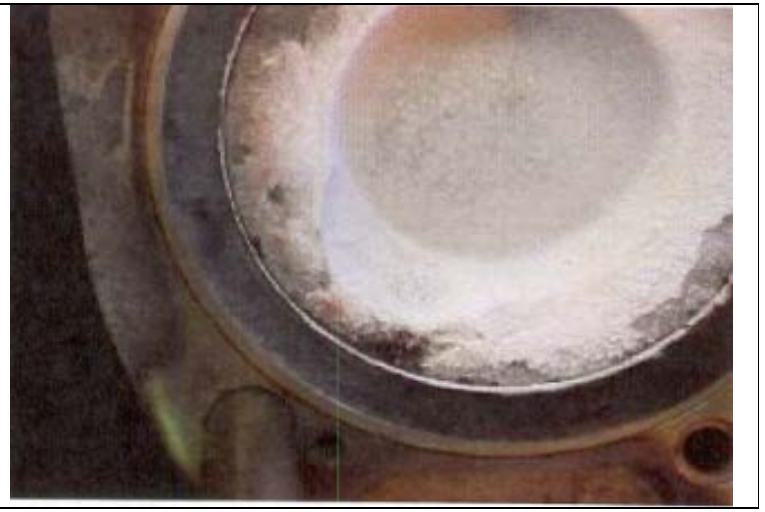
Siloxane Removal is also Necessary

- Siloxanes are a family of organic silicon compounds that originate as additives to personal care products such as soaps, shampoos, sunscreens, lotions, hair sprays, deodorants, and shaving products.
- Siloxanes pass through the WWTP processes, accumulate in sludge and volatize to form a contaminant in anaerobic digester biogas.
- When combusted, the siloxanes form a glass-like deposit that is harmful to reciprocating engines, gas turbines, microturbines, and fuel cells.

Siloxane Deposits Result in:

- A decrease in CHP project efficiency
- An increase in heat rate
- A reduction in power output
- Formation of “hot spots”
- Premature equipment failure

Microturbine Recuperator



A Piston Head

Biogas Conditioning Equipment Requirements

Biogas Contaminant Removal System Component Schematic Diagram

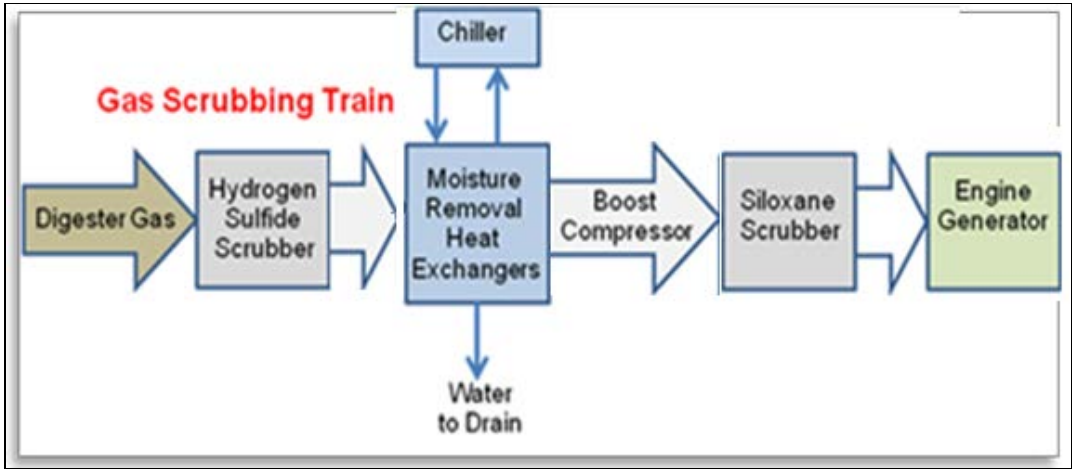


Table #5 - Electrical Generation Potential for Selected Biogas Flow Rates

Biogas Flow Rate, scfm	Thermal Energy Flow, MMBtuh[a]	Approximate Wastewater Throughput to Produce the Biogas Flow, Million Gallons per Day (MGD)	Potential Installed Generating Capacity, kW[b]	Gas Treatment Equipment Costs, $/kW
35	1.26	4	85 – 130	$2,580 – $4000
100	3.6	12	250 – 380	$1,010 – $1,640
300	10.8	36	750 – 1,135	$530 – $825
500	18.0	60	1,245 – 1,895	$350 – $540
1,000	36.0	120	2,490 – 3,790	$255 – $440
2,500	90.0	300	6,230 – 9,475	$185 – $365

WWTP Biogas Conditioning Conclusions

- Prime mover manufacturers have established “Allowable Siloxane Limits” for equipment protection
- Gas conditioning costs show a considerable “economy of scale”
- Biogas conditioning is essential to ensure that the biogas is of acceptable quality for use in biogas-fueled electrical generating equipment
- Biogas conditioning systems are custom engineered (with the removal efficiency based upon an inlet gas analysis and concentration limits for biogas utilization set by the equipment manufacturers)
- Without proper gas conditioning, maintenance costs will increase dramatically; system efficiency will deteriorate; and increased downtime will result in reduced annual energy generation.

Project Snapshot:

Partnership with Municipality

Mill Street Wastewater Treatment Plant

Rock Island, IL

ROCK ISLAND
ILLINOIS

Application/Industry: Wastewater Treatment

Capacity: 1 MW

Prime Mover: Reciprocating engine

Fuel Type: Biomass

Thermal Use: Heating

Installation Year: 2014

Highlights: The reciprocating engines at Mill Street Wastewater Treatment Plant provide power and heat for the plant as well as 4-8% of the power for city facilities.

Source: http://www.rigov.org/DocumentCenter/View/7546

Project Snapshot:

Targeting Net-Zero

Downers Grove Sanitary District
Downers Grove, IL

Application/Industry: Wastewater Treatment

Capacity: 280 kW

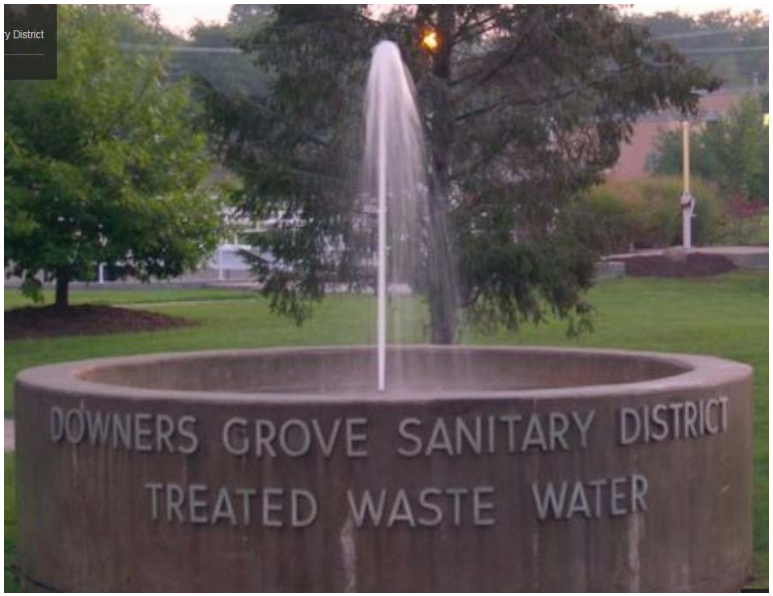
Prime Mover: Reciprocating engine

Fuel Type: Biomass

Thermal Use: Heat for the digestion process

Installation Year: 2014

Highlights: Waste grease from nearby restaurants helps power the CHP system, which offsets about 50% of the wastewater treatment plant's energy consumption.



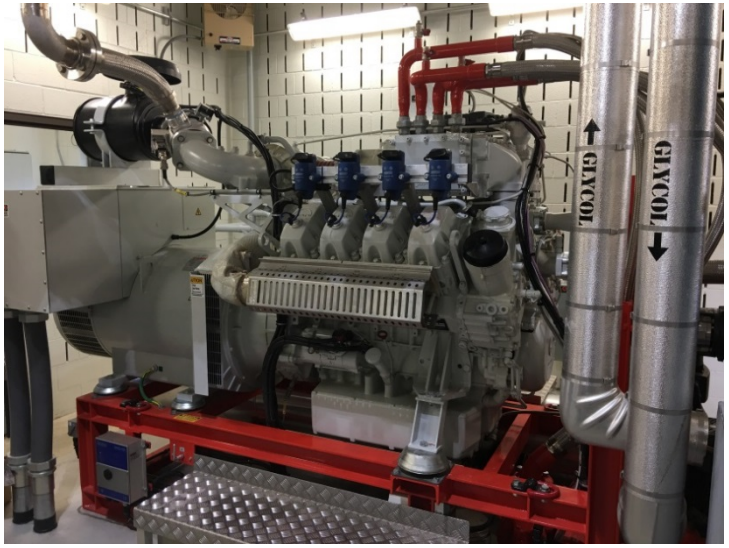
Source: http://www.midwestchptap.org/profiles/ProjectProfiles/DownersGrove.pdf

Project Snapshot:

Participating in Energy Efficiency Programs

Glenbard Wastewater Authority

Glen Ellyn, Illinois



Application/Industry: Wastewater Treatment

Capacity: 750 kW (2 x 375 kW)

Prime Mover: Reciprocating engines

Fuel Type: Biogas & natural gas

Thermal Use: Heating digesters

Installation Year: 2016

Highlights: The Glenbard Wastewater Authority received energy efficiency incentives through the Illinois Department of Commerce and Economic Opportunity's (DCEO) Public Sector CHP Pilot Program, which is part of the Illinois Energy Now Public Sector Program. To boost biogas production, the Glenbard Wastewater Authority also receives food waste and fats, oils, and greases (FOG).

Source: http://www.gbww.org/wp-content/uploads/2016/03/Glenbard-CHP-Project_Final.pdf

Available Incentives

Illinois CHP Incentives

ComEd CHP Program Changes

- Eligibility – expanded to ≥500 kW peak customers (from ≥1 MW), customers ≥10 MW exempt under FEJA
- Production Incentive
  - Still $0.07/eligible kWh after 1 year and M&V, but pre-payment of $60/kW available after 1 month of operation
  - Sliding scale incentivizing higher efficiency projects
  - No longer a cap (previously $2 million)
- Feasibility Study Incentive (no longer capped at 50%)
  - Up to $10k for CHP projects <400 kW (new)
  - Up to $25k for CHP projects ≥400 kW
- Implementation Contractor/Outreach Provider
  - ERC selected to manage a network of Technical Service Providers and to provide outreach and marketing of the ComEd CHP Program

Source: https://www.comed.com/WaysToSave/ForYourBusiness/FactSheets/CHP_FactSheet.pdf

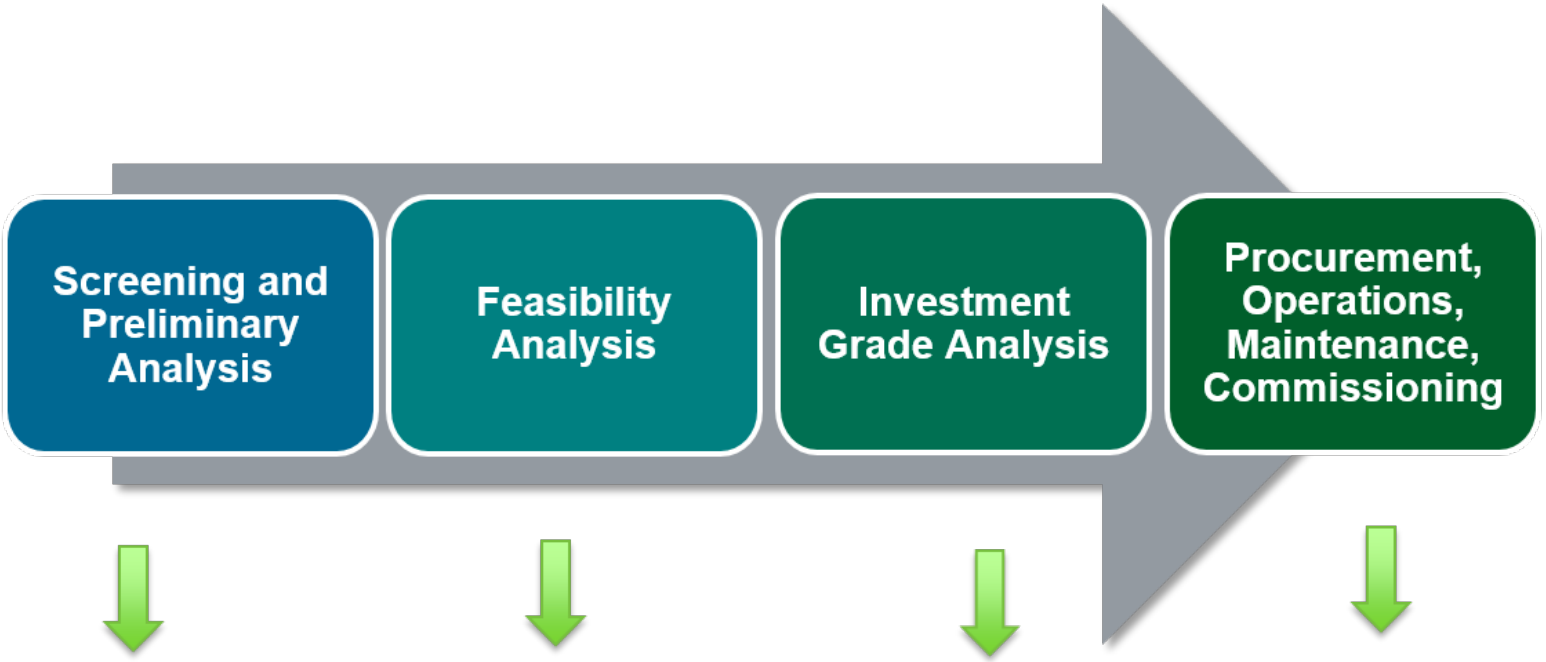
Illinois CHP Incentives

Other utilities

- **Nicor (https://nicorgasrebates.com)**
  - Incentive – $1/therm for eligible natural gas savings, under Customer Program, Capped at $500,000
  - Feasibility Studies – up to $12.5k, in addition to ComEd incentive
- **Peoples Gas (https://accel.peoplesgasdelivery.com)**
  - Incentive – $1/therm for eligible natural gas savings, under Custom Program
- **Ameren (https://www.ameren.com/illinois/energy-efficiency)**
  - Incentive – $0.12/kWh and $1.20/therm for eligible electricity and natural gas savings, under Custom Program
  - Electric cap at $500,000, natural gas cap at $100,000
  - Feasibility Studies – up to 50% of costs or 25% of annual savings identified, capped at $20k

How to Implement a CHP Project with the Help of the CHP TAP

CHP TAP Role: Technical Assistance



Quick screening questions with spreadsheet payback calculator; Advanced technical assistance to explore equipment or operational scenarios.

Perform 3rd Party reviews of site feasibility assessments: Estimates on savings, installation costs, simple paybacks, equipment sizing, and type.

Perform 3rd Party reviews of Engineering Analysis. Review equipment sizing and choices.

Review specifications and bids.

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DOE TAP CHP Screening Analysis

- High level assessment to determine if site shows potential for a CHP project
  - Qualitative Analysis
    - Energy Consumption & Costs
    - Estimated Energy Savings & Payback
    - CHP System Sizing
  - Quantitative Analysis
    - Understanding project drivers
    - Understanding site peculiarities

Annual Energy Consumption		
	Base Case	CHP Case
Purchased Electricty, kWh	88,250,160	5,534,150
Generated Electricity, kWh	0	82,716,010
On-site Thermal, MMBtu	426,000	18,872
CHP Thermal, MMBtu	0	407,128
Boiler Fuel, MMBtu	532,500	23,590
CHP Fuel, MMBtu	0	969,845
Total Fuel, MMBtu	532,500	993,435
Annual Operating Costs		
Purchased Electricity, $	$7,060,013	$1,104,460
Standby Power, $	$0	$0
On-site Thermal Fuel, $	$3,195,000	$141,539
CHP Fuel, $	$0	$5,819,071
Incremental O&M, $	$0	$744,444
Total Operating Costs, $	$10,255,013	$7,809,514
Simple Payback		
Annual Operating Savings, $		$2,445,499
Total Installed Costs, $/kW		$1,400
Total Installed Costs, $/k		$12,990,000
Simple Payback, Years		**5.3**
Operating Costs to Generate		
Fuel Costs, $/kWh		$0.070
Thermal Credit, $/kWh		($0.037)
Incremental O&M, $/kWh		$0.009
Total Operating Costs to Generate, $/kWh		**$0.042**

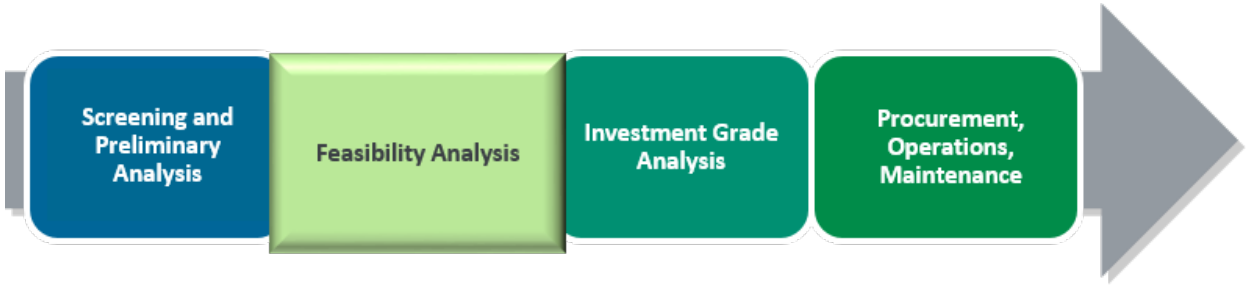
Screening Questions

- Do you pay more than $.06/kWh on average for electricity (including generation, transmission and distribution)?
- Are you concerned about the impact of current or future energy costs
  on your operations?
- Are you concerned about power reliability?
  What if the power goes out for 5 minutes… for 1 hour?
- Does your facility operate for more than 3,000 hours per year?
- Do you have thermal loads throughout the year?
  (including steam, hot water, chilled water, hot air, etc.)

Screening Questions (cont.)

- Does your facility have an existing central plant?
- Do you expect to replace, upgrade, or retrofit central plant equipment within the next 3-5 years?
- Do you anticipate a facility expansion or new construction project within the next 3-5 years?
- Have you already implemented energy efficiency measures and
  still have high energy costs?
- Are you interested in reducing your facility's impact on the environment?
- Do you have access to on-site or nearby biomass resources? (i.e., landfill gas, farm manure, food processing waste, etc.)

A Feasibility Analysis Typically Involves:



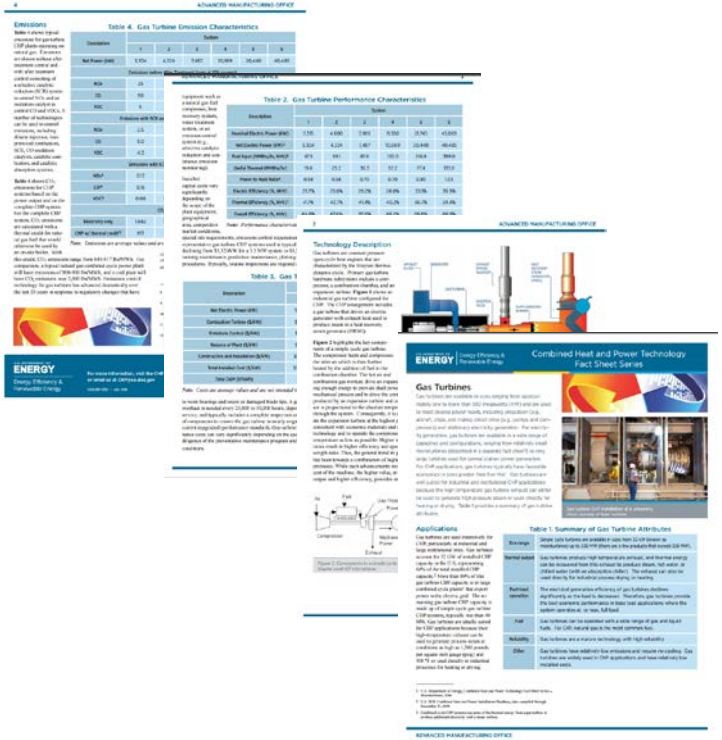
- Electrical load profiling
- Thermal load profiling
- Unit sizing
- Thermal use determination (what to do with the heat)
- Installation cost estimations
- Financial calculations (simple payback, ROI, etc.)
- Cost/savings information compared to what your facility would pay if the CHP system were not installed

Finding the Best Candidates:
Some or All of These Characteristics

- Consistent source of organic matter to produce biogas
- High and constant thermal load
- Favorable spark spread
- Need for high reliability
- Concern over future electricity prices
- Interest in reducing environmental impact
- Existing central plant
- Planned facility expansion or new construction; or equipment replacement within the next 3-5 years

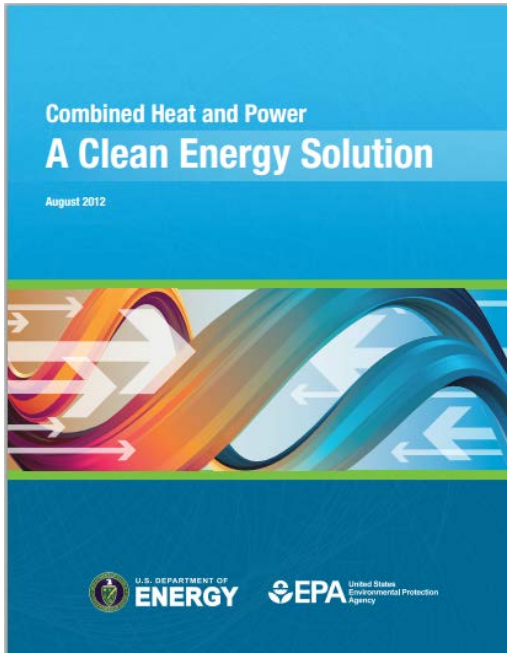
CHP Project Resources

DOE CHP Technologies Fact Sheet Series



www.energy.gov/chp-technologies

Good Primer Report

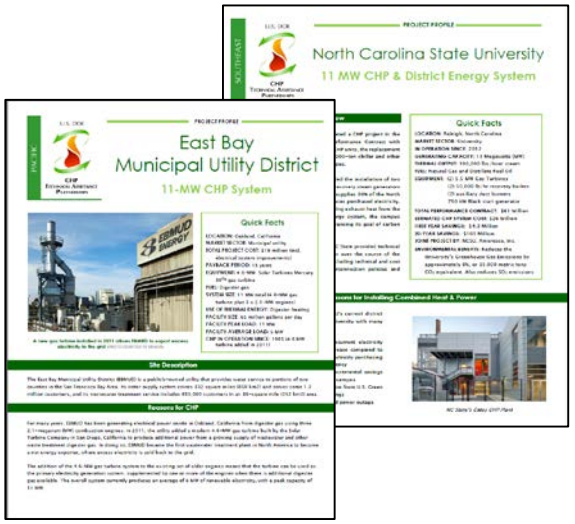


www.eere.energy.gov/chp

CHP Technical Assistance Partnerships
MIDWEST

CHP Project Resources

DOE Project Profile Database



energy.gov/chp-projects

EPA dCHPP (CHP Policies and Incentives Database

www.epa.gov/chpdchpp-chp-policies-and-incentives-database

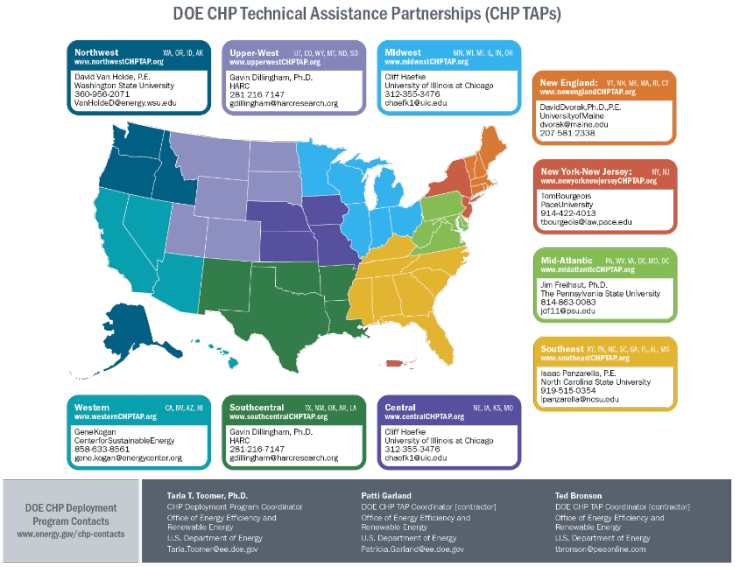
CHP Technical Assistance Partnerships
MIDWEST

CHP Project Resources

DOE CHP Installation Database
(List of all known
CHP systems in U.S.)

energy.gov/chp-installs

Low-Cost CHP Screening and Other Technical Assistance from the CHP TAP



energy.gov/CHPTAP

CHP Technical Assistance Partnerships
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What are the US DOE Industrial Assessment Centers?

- Established by the U.S. Department of Energy in 1976
- Teams of university-based faculty and student engineers (trained 3,300+ students)
- Provide no-cost energy, productivity, and waste assessments
- Serve small and medium sized US manufacturers nationwide

The IAC program has already conducted over 18,227 assessments with more than 138,162 associated recommendations. Average recommended yearly savings is $136,656.

CHP Technical Assistance Partnerships
MIDWEST

Eligibility Requirements

- Within Standard Industrial Codes (SIC) 20-39
- Located less than 150 miles of a participating university
- Gross annual sales below **$100 million**
- Fewer than **500 employees** at the plant site
- Annual energy bills more than **$100,000** and less than **$2.5 million**
- No professional in-house staff to perform the assessment

Summary

- CHP is a great tool for wastewater facilities to consume their biogas on-site and provide energy resiliency
- There are available utility energy efficiency incentives for CHP in Illinois
- Proven technologies are commercially available and cover a full range of sizes and applications

Next Steps

- Contact Midwest CHP TAP for assistance if:
  - Interested in having a Qualification Screening performed to determine if there is an opportunity for CHP at your site
  - If you already have an existing CHP plant and interested in expanding it
  - Need an unbiased 3rd Party Review of a proposal

Thank You

Graeme Miller
Assistant Director
(312) 996-3711
gmille7@uic.edu

Cliff Haefke
Director
(312) 355-3476
chaefk1@uic.edu

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